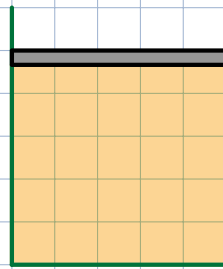


Sat. liq
 $p = 100 \text{ kPa}$
 $m = 0.2 \text{ kg}$



Sat. vapor
 $p = 100 \text{ kPa}$

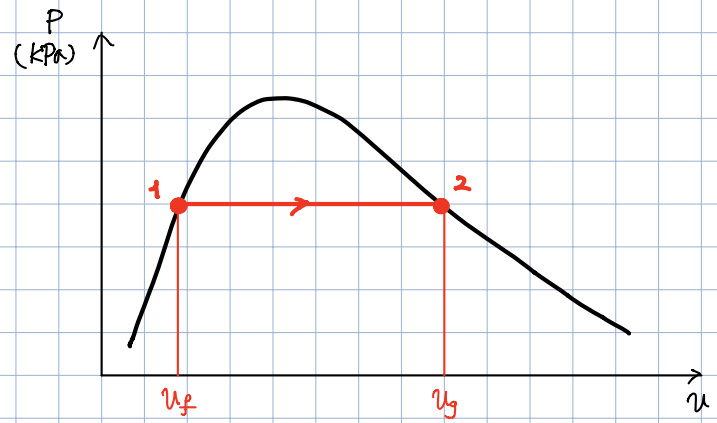


TABLE A-1 Saturated water—Pressure table										TABLE A-2 Saturated water—Pressure table									
Pressure, MPa	Sat. liquid			Sat. vapor			Quality constant			Pressure, MPa	Sat. liquid			Sat. vapor			Quality constant		
	T , °C	v_f , m³/kg	h_f , kJ/kg	T , °C	v_g , m³/kg	h_g , kJ/kg	x	v , m³/kg	h , kJ/kg		T , °C	v_f , m³/kg	h_f , kJ/kg	T , °C	v_g , m³/kg	h_g , kJ/kg	x	v , m³/kg	h , kJ/kg
0.01	0.01	0.001000	0.01	0.01	206.84	2689.6	0.01	0.001000	0.01	0.01	0.001000	0.01	0.01	206.84	2689.6	0.01	0.001000	0.01	
0.05	0.05	0.001000	0.05	0.05	240.06	2706.3	0.05	0.001000	0.05	0.05	0.001000	0.05	0.05	240.06	2706.3	0.05	0.001000	0.05	
0.10	0.10	0.001000	0.10	0.10	253.86	2706.3	0.10	0.001000	0.10	0.10	0.001000	0.10	0.10	253.86	2706.3	0.10	0.001000	0.10	
0.20	0.20	0.001000	0.20	0.20	270.13	2706.3	0.20	0.001000	0.20	0.20	0.001000	0.20	0.20	270.13	2706.3	0.20	0.001000	0.20	
0.30	0.30	0.001000	0.30	0.30	289.06	2706.3	0.30	0.001000	0.30	0.30	0.001000	0.30	0.30	289.06	2706.3	0.30	0.001000	0.30	
0.40	0.40	0.001000	0.40	0.40	307.03	2706.3	0.40	0.001000	0.40	0.40	0.001000	0.40	0.40	307.03	2706.3	0.40	0.001000	0.40	
0.50	0.50	0.001000	0.50	0.50	323.84	2706.3	0.50	0.001000	0.50	0.50	0.001000	0.50	0.50	323.84	2706.3	0.50	0.001000	0.50	
0.60	0.60	0.001000	0.60	0.60	340.01	2706.3	0.60	0.001000	0.60	0.60	0.001000	0.60	0.60	340.01	2706.3	0.60	0.001000	0.60	
0.70	0.70	0.001000	0.70	0.70	355.83	2706.3	0.70	0.001000	0.70	0.70	0.001000	0.70	0.70	355.83	2706.3	0.70	0.001000	0.70	
0.80	0.80	0.001000	0.80	0.80	371.40	2706.3	0.80	0.001000	0.80	0.80	0.001000	0.80	0.80	371.40	2706.3	0.80	0.001000	0.80	
0.90	0.90	0.001000	0.90	0.90	386.71	2706.3	0.90	0.001000	0.90	0.90	0.001000	0.90	0.90	386.71	2706.3	0.90	0.001000	0.90	
1.00	1.00	0.001000	1.00	1.00	401.06	2706.3	1.00	0.001000	1.00	1.00	0.001000	1.00	1.00	401.06	2706.3	1.00	0.001000	1.00	
1.20	1.20	0.001000	1.20	1.20	438.91	2706.3	1.20	0.001000	1.20	1.20	0.001000	1.20	1.20	438.91	2706.3	1.20	0.001000	1.20	
1.50	1.50	0.001000	1.50	1.50	481.13	2706.3	1.50	0.001000	1.50	1.50	0.001000	1.50	1.50	481.13	2706.3	1.50	0.001000	1.50	
2.00	2.00	0.001000	2.00	2.00	540.06	2706.3	2.00	0.001000	2.00	2.00	0.001000	2.00	2.00	540.06	2706.3	2.00	0.001000	2.00	
3.00	3.00	0.001000	3.00	3.00	645.81	2706.3	3.00	0.001000	3.00	3.00	0.001000	3.00	3.00	645.81	2706.3	3.00	0.001000	3.00	
4.00	4.00	0.001000	4.00	4.00	726.01	2706.3	4.00	0.001000	4.00	4.00	0.001000	4.00	4.00	726.01	2706.3	4.00	0.001000	4.00	
5.00	5.00	0.001000	5.00	5.00	788.34	2706.3	5.00	0.001000	5.00	5.00	0.001000	5.00	5.00	788.34	2706.3	5.00	0.001000	5.00	
6.00	6.00	0.001000	6.00	6.00	835.76	2706.3	6.00	0.001000	6.00	6.00	0.001000	6.00	6.00	835.76	2706.3	6.00	0.001000	6.00	
7.00	7.00	0.001000	7.00	7.00	871.90	2706.3	7.00	0.001000	7.00	7.00	0.001000	7.00	7.00	871.90	2706.3	7.00	0.001000	7.00	
8.00	8.00	0.001000	8.00	8.00	898.06	2706.3	8.00	0.001000	8.00	8.00	0.001000	8.00	8.00	898.06	2706.3	8.00	0.001000	8.00	
9.00	9.00	0.001000	9.00	9.00	915.86	2706.3	9.00	0.001000	9.00	9.00	0.001000	9.00	9.00	915.86	2706.3	9.00	0.001000	9.00	
10.00	10.00	0.001000	10.00	10.00	927.03	2706.3	10.00	0.001000	10.00	10.00	0.001000	10.00	10.00	927.03	2706.3	10.00	0.001000	10.00	
12.00	12.00	0.001000	12.00	12.00	951.13	2706.3	12.00	0.001000	12.00	12.00	0.001000	12.00	12.00	951.13	2706.3	12.00	0.001000	12.00	
15.00	15.00	0.001000	15.00	15.00	999.46	2706.3	15.00	0.001000	15.00	15.00	0.001000	15.00	15.00	999.46	2706.3	15.00	0.001000	15.00	
20.00	20.00	0.001000	20.00	20.00	1162.63	2706.3	20.00	0.001000	20.00	20.00	0.001000	20.00	20.00	1162.63	2706.3	20.00	0.001000	20.00	
30.00	30.00	0.001000	30.00	30.00	1436.10	2706.3	30.00	0.001000	30.00	30.00	0.001000	30.00	30.00	1436.10	2706.3	30.00	0.001000	30.00	
40.00	40.00	0.001000	40.00	40.00	1676.34	2706.3	40.00	0.001000	40.00	40.00	0.001000	40.00	40.00	1676.34	2706.3	40.00	0.001000	40.00	
50.00	50.00	0.001000	50.00	50.00	1886.76	2706.3	50.00	0.001000	50.00	50.00	0.001000	50.00	50.00	1886.76	2706.3	50.00	0.001000	50.00	
60.00	60.00	0.001000	60.00	60.00	2068.97	2706.3	60.00	0.001000	60.00	60.00	0.001000	60.00	60.00	2068.97	2706.3	60.00	0.001000	60.00	
70.00	70.00	0.001000	70.00	70.00	2225.27	2706.3	70.00	0.001000	70.00	70.00	0.001000	70.00	70.00	2225.27	2706.3	70.00	0.001000	70.00	
80.00	80.00	0.001000	80.00	80.00	2359.08	2706.3	80.00	0.001000	80.00	80.00	0.001000	80.00	80.00	2359.08	2706.3	80.00	0.001000	80.00	
90.00	90.00	0.001000	90.00	90.00	2473.99	2706.3	90.00	0.001000	90.00	90.00	0.001000	90.00	90.00	2473.99	2706.3	90.00	0.001000	90.00	
100.00	100.00	0.001000	100.00	100.00	2576.99	2706.3	100.00	0.001000	100.00	100.00	0.001000	100.00	100.00	2576.99	2706.3	100.00	0.001000	100.00	

a) the Volume change

$$u_{fg} = u_g - u_f$$

$$= (1.6941) - (0.001043)$$

$$= 1.6931 \text{ m}^3/\text{kg}$$

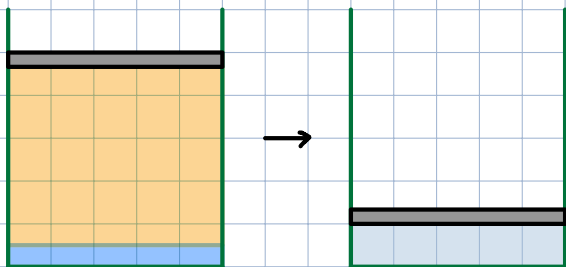
$$\Delta V = m u_{fg} = (0.2 \text{ kg}) \cdot (1.6931 \text{ m}^3/\text{kg})$$

$$= 0.3386 \text{ m}^3$$

b) the amount of energy transferred to the water

Energy $\rightarrow$ the enthalpy of vaporization at that pressure

$$E = m h_{fg} = (0.2 \text{ kg}) \cdot (2257.5 \text{ kJ/kg}) = 451.5 \text{ kJ}$$



$$T_1 = 25^\circ\text{C}$$

$$p_1 = 100 \text{ kPa}$$

air + liq. water (1 kg)

$$V_1 = 1 \text{ m}^3$$

$$T_2 = 180^\circ\text{C}$$

air + water vapor

$$V_2 = 0.1 \text{ m}^3$$

Air, ideal gas

$$C_u = 0.728 \text{ kJ/kg}\cdot\text{K}$$

$$R = 0.287 \text{ kJ/kg}\cdot\text{K}$$

$$C_p - C_u = R$$

$$C_p = C_u + R$$

a) State 2 is ideal mixture $\rightarrow p_2 = ?$

(Neglect any air dissolved in water)

b) $pV^n = \text{const} \rightarrow W = ?$

c) Determine the heat transfer from the surrounding

(a) State 2 = air + water vapor

$$p_2 = p_{2, \text{air}} + p_{2, \text{wv}}$$

$$p u = RT$$

$$p = nRT/V$$

State 1: Table A-4: $T_1 = 25^\circ\text{C} \rightarrow p_{\text{sat}} = 3.17 \text{ kPa}$

$$\text{air + liq. water} \rightarrow p_1 = p_{1, \text{wv}} + p_{1, \text{air}} = 100 \text{ kPa}$$

$$\therefore p_{1, \text{air}} = 96.83 \text{ kPa}$$

$$p_1 V_1 = n R T_1 \rightarrow n = \frac{p_1 V_1}{R T_1} \quad (\because \text{Volume occupied by liquid is neglected})$$

$$m_{\text{air}} = \frac{(96.83 \text{ kPa}) \cdot (1 \text{ m}^3)}{(0.287 \text{ kJ/kg}\cdot\text{K}) \cdot (298 \text{ K})} = 1.13 \text{ kg}$$

State 2:

$$p_2 V_2 = n R T_2$$

$$p_{2, \text{air}} = \frac{n R T_2}{V_2}$$

$$= \frac{(1.13) \cdot (0.287) \cdot (453)}{(0.1)} = 1469.1 \text{ kPa}$$

$$\text{Table A-4: } T_2 = 180^\circ\text{C} \rightarrow p_{2, \text{wv}} = 1002.8 \text{ kPa}$$

$$p_2 = (1469.1 \text{ kPa}) + (1002.8) = 2471.9 \text{ kPa}$$

Ans. (a)

(b) $pV^n = \text{const} \rightarrow W = ?$

$$W = \int_{V_1}^{V_2} p dV \leftarrow pV^n = C$$

$$= \frac{p_2 V_2 - p_1 V_1}{1-n}$$

$$= \frac{(2471.9)(0.1) - (100)(1)}{1-1.393}$$

$$= -874.53 \text{ kJ}$$

Ans (b)

$$p_1 V_1^n = p_2 V_2^n$$

$$(100) \cdot (1)^n = (2471.9) (0.1)^n$$

$$(0.1)^n = 100 / 2471.9$$

$$n \log(0.1) = \log(100 / 2471.9)$$

$$\therefore n = 1.393$$

(c) Determine the heat transfer from the surrounding

Energy $\rightarrow$ the enthalpy of vaporization

$$\Delta E = m h_{fg} = \Delta H = Q - W$$

$$Q = \Delta H + W$$

$$Q = \{\Delta H\}_{\text{air}} + \{\Delta H\}_{\text{wv}} + \{\Delta H\}_{\text{wl}} + W$$

$$m_{1,\text{wl}} = 1 \text{ kg} \longrightarrow V_2 = 0.1 \text{ m}^3$$

if all liq. water turned into sat. vapor, $V_2 = 0.1 \text{ m}^3/\text{kg}$

$$\text{Table A-4: } T_2 = 180^\circ\text{C} \longrightarrow \begin{aligned} u_f &= 0.061127 \\ u_g &= 0.19384 \end{aligned}$$

$$\begin{aligned} u_2 &= \frac{V_2}{m} \\ u_g &= \frac{V_2}{m_{2,\text{wv}}} \longrightarrow m_{2,\text{wv}} = \frac{V_2}{u_g} = \frac{0.1 \text{ m}^3}{0.19384 \text{ m}^3/\text{kg}} = 0.51589 \text{ kg} \\ m_{2,\text{wl}} &= 1 - 0.51589 = 0.484 \text{ kg} \end{aligned}$$

$$\begin{aligned} \{\Delta H\}_{\text{air}} &= m_{\text{air}} \cdot C_p (T_2 - T_1) \leftarrow C_p = C_v + R \\ &= (1.13 \text{ kg}) \cdot (1.015 \text{ kJ/kg} \cdot \text{K}) \cdot (180 - 25 \text{ K}) \\ &= 177.78 \text{ kJ} \end{aligned}$$

$$\begin{aligned} \{\Delta H\}_{\text{wv}} &= m_{2,\text{wv}} \cdot h_{2,\text{wv}} - m_{1,\text{wv}} \cdot h_{1,\text{wv}} \leftarrow T = 180^\circ\text{C} \longrightarrow \begin{aligned} h_f &= 763.05 \\ h_g &= 2014.2 \\ h_g &= 2771.2 \end{aligned} \\ &= (0.51589 \text{ kg}) \cdot (1802.16) \\ &= 929.73 \text{ kJ} \end{aligned}$$

$$\{\Delta H\}_{\text{wl}} = m_{2,\text{wl}} \cdot h_{2,\text{wl}} - m_{1,\text{wl}} \cdot h_{1,\text{wl}}$$

$$\begin{aligned} &= (0.484) \cdot (763.05) - (1) \cdot (104.83) \\ &= 264.48 \text{ kJ} \end{aligned}$$

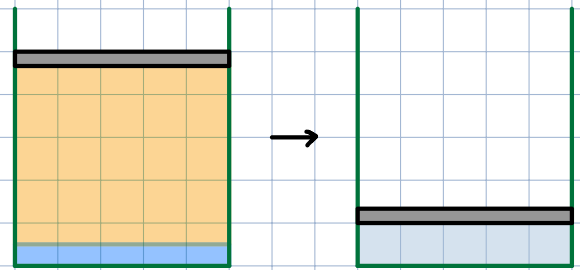
$$x_2 = \frac{0.51589 \text{ kg}}{1 \text{ kg}} = 0.51589 \longrightarrow h_{2,\text{wv}} = h_f + x_2 (h_{fg}) = 1802.16$$

$$Q = \{\Delta H\}_{\text{air}} + \{\Delta H\}_{\text{wv}} + \{\Delta H\}_{\text{wl}} + W$$

$$= (177.78) + (929.73) + (264.48) + (-374.53)$$

$$= 997.46 \text{ kJ}$$

Ans. (c)



$$T_1 = 25^\circ\text{C}$$

$$p_1 = 100 \text{ kPa}$$

air + liq. water (1 kg)

$$V_1 = 1 \text{ m}^3$$

$$T_2 = 180^\circ\text{C}$$

air + water vapor

$$V_2 = 0.1 \text{ m}^3$$